MODIS SCIENCE DATA SUPPORT TEAM PRESENTATION

September 20, 1991

AGENDA

1. Action Items

2. MODIS TLCF

3. MODIS Image Registration

4. MODIS Airborne Simulator

5. NetCDF

6. Processing Overview

7. Data Management Plan

8. MODIS Level-1 Granule Size

ACTION ITEMS (Corrected list):

05/03/91 [Lloyd Carpenter and Tom Goff]: Prepare a Level-1
processing assumptions, questions and issues list, to be
distributed to the Science Team Members and the MCST for comment.
(A revised version of the overview is included in the handout.)
STATUS: Open. Due date 06/07/91.

06/07/91 [Liam Gumley]: Speak to Alan Strahler, when he returns,
regarding his MAS requirements. (A message was left on
Strahler's recorder.) STATUS: Open. Due date 07/05/91

05/31/91 [Al McKay and Phil Ardanuy]: Examine the effects of
MODIS data product granule size on Level-1 processing,
reprocessing, archival, distribution, etc. (A summary is
included in the handout.) STATUS: Closed Due Date
06/21/91

06/28/91 [Lloyd Carpenter and Tom Goff]: Prepare a detailed list
of scheduler assumptions in relation to Level-1 MODIS processing
scenarios. STATUS: Open. Due date 07/26/91.

08/30/91 [Team]: Determine what the SDST should present at the
Science Team Meeting, and who should make the presentations. (A
list of suggested topics was included in the previous handout.)
STATUS: Open. Due date 09/06/91.

08/30/91 [Team]: Draft a schedule of work for the next 12 months.
Include primary events and milestones, documents to be produced,
software development, MAS support, etc. STATUS: Open. Due date
09/27/91.

08/30/91 [Team]: Contact Sol Broder regarding the MODIS interface
with the scheduler. (Still trying.) STATUS: Open. Due date
09/13/91.

MODIS TEAM LEADER COMPUTING FACILITY (TLCF)

OUTLINE

Functions:

Software development for MODIS Level-1A and Level-1B processing

Software development for MODIS utilities

Integration, testing and debugging of Team Member supplied algorithms

Generate simulated MODIS Level-0 data

Software testing and validation using MODIS simulated and real data

Computing resources for the MODIS Team Leader and Team Members

Computing resources for the MODIS Calibration Support Team (MCST)

Computing resources for the MODIS Science Data Support Team (SDST)

Computing resources for the MODIS Administrative Support Team (MAST)

Software documentation

Size:

Equivalent to EOSDIS Core System for MODIS processing

On-line storage of TBD (100 MByte)

Total disk storage of TBD (5 GByte)

I/O TBD

Displays TBD

Communications TBD

MODIS IMAGE REGISTRATION

STATUS

Notes on meeting with Bill Clark (CSC) on September 10, 1991:

Used FFT on Landsat 1,2,3

Edge detection algorithm used for Landsat 4,5

Loss due to sun angle, <u>haze</u>, etc.

Land/water interfaces are the least reliable ground control points (GCPs) because they move

There is no adequate atmospheric model

EOSAT: Select 30 GCPs on each path over the U.S.; up to 30 scenes per swath

Sequence of tapes   HDDTR → HDDTA → HDDTP → CCT

      HDDTR to A   tape takes 7.8 min/scene   100 scenes/day

      HDDTA to P   tape takes 22 min/scene   50 scenes/day

      HDDTP to CCT tape takes 45 min/scene   10 scenes/day

      on MPP (Massively Parallel Processor)

      Ingest data at 100 Mbits/sec

Contact R.J. Thompson and __ Olson at EDC for initial cost of software (cost of development).

Reference in 1985 ACSM – ASPRS Fall Convention

      ACSM – American Congress of Surveying and Mapping

      ASPRS – American Society for Photogrammetry and Remote Sensing

Can put 300 to 3000 high density tapes onto one optical tape

Things we need to do:

1)   Talk to people

2)   Get some maps with 100 to 500 meter features. Look for edges.

3)   Make a list of what could be good GCPs. Make a feature list.

4)   Look at MAS data.

5)   Look for band dependence. GCPs depend on frequency bands, gain, radiance range, etc.

6)   Think through feature types. Bridges, coast lines

Notes from phone call with Ken Jones at JPL (818/354-2242) (works with David Diner). They are working on image registration for MISR. They do image registration for interplanetary missions etc.:

MISR has 9 cameras. Correct for stereo.

They have been talking to GE people about spacecraft stability.
The orbital position is off by several pixels, 3 sigma.
There is slow drift plus vibrations at the 1/4 pixel level, 3 sigma.
They will update navigation information obtained from EOS using GCPs

They are working on automating the registration process.

Coastlines are available on CD Rom

A Digital Elevation Model is essential.

Their aim is for 1/4 pixel, but they may have to drop back to 1/3 pixel.

Information should be available in the earlier MISR Data Processing Plans

<u>Progress on MAS Level-1B processing system development</u>

<u>Progress up to 19 September 1991</u>

(1) MAS software development
Development of the MAS geolocation software has continued, and is almost to the stage of an integrated Version 1.0. Updated code has been written to carefully check the INS input dataset before regressions are generated. This allows confirmation of the selection of straight line flight tracks, and verification of the continuity of the INS dataset. The changes made are detailed in the "MAS geolocation software assumptions and methodology" included in this report. The latitude, longitude, scan angle, azimuth angle, solar zenith angle and solar azimuth angle can now be computed for any given pixel on any given MAS scanline. An integrated Version 1.0 of the geolocation code should be ready within a week.

(2) MAMS test data from Wisconsin
Chris Moeller was contacted regarding the delivery of the rest of the MAMS test dataset. The magtapes arrived on 09/13/91 and were read on the LTP VAX on the same day. Review of the data obtained indicated that some data was missing from the complete set. I contacted Chris about this and we decided that the first tape which I brought back from Wisconsin had an error about half way through. I had initially assumed that this was the end of the data on the tape. Chris Moeller will recopy the tape and send it as soon as possible. This section of the data is important because it contains the test region which Chris and I looked at in Wisconsin.

(3) Meeting with Mike King
I met with Mike King on 09/06/91. He said that plans for the November 13 deployment of the MAS are on schedule. The FIRE field phase will run from November 13 to December 7, and will be based in San Antonio TX. We should not expect to receive any MAS Level-1A data until the aircraft returns from the field. It will be possible for those in the field to look at the MAS data using the portable Quick View System (QVS) developed by Jedlovec et al at MSFC. There may be 1 or 2 engineering flights of the MAS before November but he was unsure if the data would be available to us by November. I asked Mike how we could help in preparing for any MAS presentations at the upcoming calibration and Science Team meetings. Ken Brown will be giving the presentation at the calibration meeting, and Mike did not indicate that he needed any support for that meeting. For the Science Team meeting, Mike asked that I prepare brief summaries on the MAS calibration and geolocation code development which he could use to create his own slides or viewgraphs. I have included drafts of these summaries with this report as "assumptions and methodology" descriptions. Mike did not have any problem with including the INS data as a separate part of the dataset. He also showed me a memo he had just sent out dated 09/05/91 which describes the current MAS status. This memo includes details of the proposed spectral band selection for November and also for the full MAS configuration in 1992.

(4) Communication with Chris Moeller.
Chris relayed to me some points that came out of a discussion with Jeff Myers at ARC. It is planned to include in the MAS Level-1A data stream an indicator which identifies the spectral band assigned to each channel. There is space for this in the current Level-1A header on each scanline but it is not used at present. Ames has no problem with delivering MAS data on Exabyte tape. I will check with Mike King as whether we should go through him to order data from Ames. The MAS will only use the new Ames scanhead (MAMS can use either new or old scanhead).

(5) Other issues.

For the MODIS Science Team Meeting, it may be useful to survey the Team Members to ask questions like

(a) Do you want to receive MAS data?

(b) How much do you want? (Full-resolution, sub-sampled)

(c) What distribution media do you need? (9-track tape, Exabyte, Internet)

(d) What computer system will you be using? (NETCDF support?)

(e) Are you interested in straight line flight tracks only, or turns as well?

(f) Is there anything missing from the Level-1B dataset which you will need?

MAS calibration software assumptions and methodology

(01) MAS data format
The MAS Level-1A data will be supplied in the format currently used by Ames Research Center for Multispectral Atmospheric Mapping Sensor (MAMS) data. MAMS has been used as the model for MAS calibration software development.

(02) Number of channels and spectral bands
The MAS will record 12 image channels, where each image channel may be selected from up to 50 spectral bands. The spectral band assigned to each channel is selected pre-flight and does not change during flight.

(03) Number of bits per channel
MAS image data may be recorded at either 8 bit or 10 bit resolution. This is set pre-flight and does not change during flight.

(04) Visible band calibration
The MAS has no onboard visible calibration capability. MAS visible wavelength image bands are calibrated on the ground either before or after flight missions. A linear calibration (slope and intercept) from digital counts to radiance is generated for each visible band and does not change during flight.

(05) Infrared band calibration.
The MAS has an onboard infrared calibration capability. Two temperature controlled blackbodies are viewed during every scan. The blackbody temperatures and digital counts are used to generate a linear calibration (slope and intercept) from digital counts to radiance for every individual scanline. The valid temperature range for calibration is assumed to be 150K to 373K.

(06) Data quality checking
No quality checking is performed on the MAS image data. Certain items in the MAS engineering data are checked. The time and scan number are checked to ensure continuity. The time is checked against the scan number to ensure scan rate continuity. The blackbody counts for all channels are checked to ensure continuity, and that they lie within the range defined by the number of bits for that channel (e.g. 8 bit implies a range of 0-255). The blackbody temperatures for all channels are checked to ensure continuity, and that they lie within the range 0K to 373K. The blackbody counts and temperatures for the infrared channels are checked to ensure that the values for the hot blackbody are greater than those for the cold black body. If problems are detected with the blackbody data in any channel, then the calibration slope and intercept for that channel are set to zero for that scanline.

(07) Output data
The MAS visible bands have radiance computed in units of milliWatts per square centimeter per steradian per micron. The MAS infrared bands have radiance computed in units of milliWatts per square centimeter per steradian per wavenumber. These values are scaled appropriately and stored as 16 bit integers. The blackbody counts, temperatures, and calibration slope and intercept data are also stored for every MAS channel on every scanline.

MAS geolocation software assumptions and methodology

(01) Geolocation data format
Geolocation data for the MAS is recorded continuously during flight by the ER-2 Inertial Navigation System (INS). The important parameters are time, aircraft latitude, longitude, heading and altitude. The INS updates these values approximately every 5 seconds. The INS dataset is an ASCII file which is supplied separate to the MAS Level-1A dataset.

(02) Geolocation strategy
Geolocation is only performed for portions of a flight where the aircraft flew a straight and level line. Geolocation data is obtained solely from the INS data, with no reference to the MAS imagery. Straight line flight tracks are identified by manual inspection of the change in aircraft heading with time. The start and end times of the straight line flight tracks are noted. Linear regressions for aircraft latitude, longitude, heading and altitude versus time are computed for the straight line flight tracks.

(03) MAS image geolocation

To geolocate a given MAS straight line flight track, the MAS start time and scanline number at the beginning of the flight track are determined. These are used as a reference for the rest of the flight track, since MAS times are truncated to whole seconds. The scanline number and scan rate are used to determine the time elapsed to subsequent scanlines in the flight track. Once the time for a given scanline is computed, the linear regression relationships are used to compute aircraft latitude, longitude, heading and altitude at that time. Latitudes and longitudes are then computed for every 10th pixel on that scanline (pixels 1, 10, 20, 30, ..., 690, 700, 710, 716). Solar zenith and azimuth angles, and aircraft scan and azimuth angles are also computed for every 10th pixel. Every scanline in a straight line flight track is geolocated in this way. Scanlines which are not included in straight line flight tracks have no geolocation data computed. However it should be noted that the INS data is still available during these sections.

(04) Data quality checking
The whole INS dataset is checked separately before the geolocation computations are done. Plots of aircraft time versus record number, and aircraft latitude, longitude, heading and altitude versus time are inspected for continuity and validity. The INS dataset is then checked for small continuity errors which confirm the selection of straight line flight track times. The method is to check the value of a parameter at a given time versus the previous value of the parameter. In summary,
(a) Time is checked to ensure it is not less than, or more than one minute greater than the previous time,
(b) Latitude is checked to ensure it does not differ from the previous latitude by more than 0.2 degrees,
(c) Longitude is checked to ensure it does not differ from the previous longitude by more than 0.2 degrees,
(d) Heading is checked to ensure it does not differ from the previous heading by more than 1 degree,
(e) Altitude is checked to ensure it does not differ from the previous altitude by more than 100 meters,
(f) Pitch is checked to ensure it does not differ from the previous pitch by more than 2.5 degrees.

(05) Output data
The geolocation parameters are stored for every 10th pixel on every scanline (pixels 1, 10, 20, 30, ..., 690, 700, 710, 716). The geolocation parameters stored are

(a) Pixel latitude (degrees, -90 is South, +90 is North),
(b) Pixel longitude (degrees, -180 is West, 0 is Greenwich, +180 is East),
(c) Pixel scan angle (degrees),
(d) Pixel azimuth angle (degrees),
(e) Solar zenith angle at pixel (degrees),
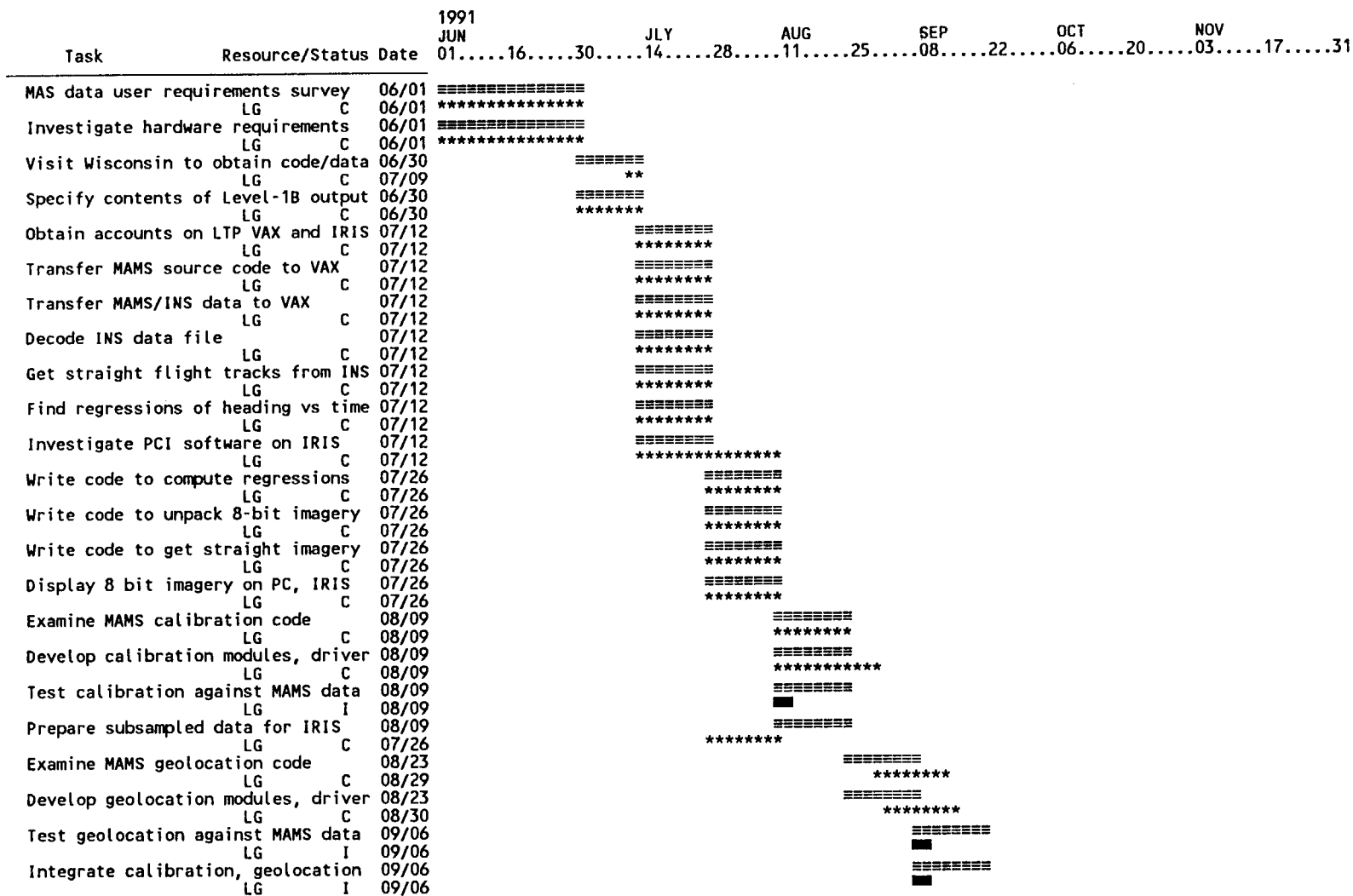(f) Solar azimuth angle at pixel (degrees).
These values are scaled appropriately and stored as 32 bit integers. The original INS dataset
will also be stored separately as part of the output.

Date: 09/19/91
Each Symbol = 2 Days

MAS Level-1B Processing System Development at GSFC

MAS Level-1B Processing System
MAS01

≡ Planned
■ Actual
* Completed
M Milestone

```
                                           1991
                                           JUN           JLY         AUG         SEP         OCT         NOV
    Task            Resource/Status Date   01.....16.....30.....14.....28.....11.....25.....08.....22.....06.....20.....03.....17.....31

MAS data user requirements survey   06/01  ================
                         LG       C 06/01  ***************
Investigate hardware requirements   06/01  ================
                         LG       C 06/01  ****************
Visit Wisconsin to obtain code/data 06/30                  =======
                         LG       C 07/09                     **
Specify contents of Level-1B output 06/30                  ========
                         LG       C 06/30                  *******
Obtain accounts on LTP VAX and IRIS 07/12                        ========
                         LG       C 07/12                        ********
Transfer MAMS source code to VAX    07/12                        ========
                         LG       C 07/12                        ********
Transfer MAMS/INS data to VAX       07/12                        ========
                         LG       C 07/12                        ********
Decode INS data file                07/12                        ========
                         LG       C 07/12                        ********
Get straight flight tracks from INS 07/12                        ========
                         LG       C 07/12                        ********
Find regressions of heading vs time 07/12                        ========
                         LG       C 07/12                        ********
Investigate PCI software on IRIS    07/12                        ================
                         LG       C 07/12                        ****************
Write code to compute regressions   07/26                                ========
                         LG       C 07/26                                ********
Write code to unpack 8-bit imagery  07/26                                ========
                         LG       C 07/26                                ********
Write code to get straight imagery  07/26                                ========
                         LG       C 07/26                                ********
Display 8 bit imagery on PC, IRIS   07/26                                ========
                         LG       C 07/26                                ********
Examine MAMS calibration code       08/09                                       ========
                         LG       C 08/09                                       ********
Develop calibration modules, driver 08/09                                       ========
                         LG       C 08/09                                       ***********
Test calibration against MAMS data  08/09                                       ========
                         LG       I 08/09                                       ■
Prepare subsampled data for IRIS    08/09                                       ========
                         LG       C 07/26                                ********
Examine MAMS geolocation code       08/23                                              ========
                         LG       C 08/29                                              ********
Develop geolocation modules, driver 08/23                                              ========
                         LG       C 08/30                                               ********
Test geolocation against MAMS data  09/06                                                      ========
                         LG       I 09/06                                                      ■
Integrate calibration, geolocation  09/06                                                      ========
                         LG       I 09/06                                                      ■
```

Date: 09/19/91
Each Symbol = 2 Days

≡ Planned
■ Actual
* Completed
M Milestone

MAS Level-1B Processing System Development at GSFC

```
                                   1991
                                   JUN           JLY         AUG         SEP         OCT         NOV
                                   01.....16.....30.....14.....28.....11.....25.....08.....22.....06.....20.....03.....17.....31
   Task          Resource/Status Date
Introduce users to IRIS imagery    09/06                                            ========
                 LG
Convert Level-1B to netCDF (TEG)   09/20                                               ========
                 LG           I     09/13
Process new MAMS data set          09/20                                            ■
                 LG                                                                  =======
Fix any bugs found                 09/20                                            ========
                 LG
Incorporate any changes from users 09/20                                            ========
                 LG
Integrate documentation, user guide 10/04                                                   ========
                 LG
Create netCDF output, write to tape 10/04                                                   ========
                 LG
Test netCDF access routines (TEG)  10/04                                                    ========
                 LG
Confirm MAS delivery with Ames     10/04                                                    ========
                 LG
First MAS flight for FIRE          11/18                                                                       M
                 LG
```
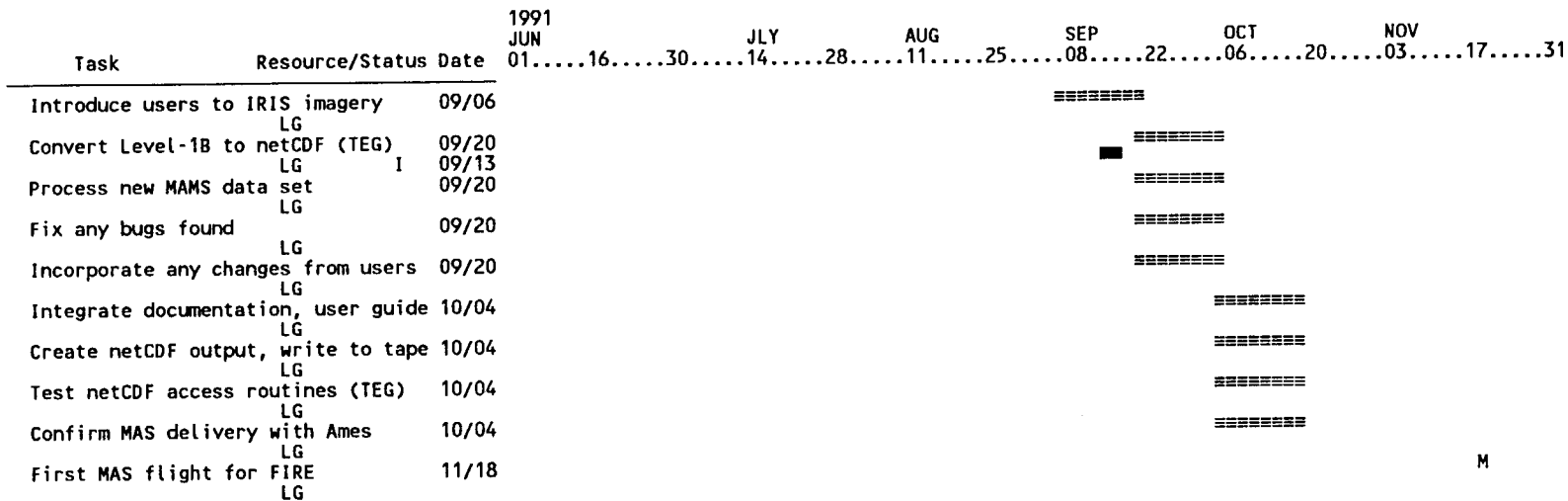
Comments on the proposed use of
the NetCDF format
for MAS data distribution

The NetCDF routines have been installed on the LTP VAX in the system library SYS$LIBRARY:NETCDF.OLB/LIB. NCDUMP and NCGEN are on the LTP VAX machine as system programs available to all users. LTPIRIS2 has all the sources transferred to this UNIX machine and will be installed shortly.

The user selects the data type that NetCDF will use when placing the data in to the data set. A multidimensional array of type Integer*2 can be used for the instrument science (detector) data. This is 92.5% of the data. Real numbers can be used for the calibration, anchor points, and interpolated INS values (7.2%), and integer*2 for status (1/10 %).

NetCDF has an attribute data type that includes predetermined units such as degrees celsius. The proposed MAS data format would have radiances scaled by a TBD factor in order to represent calibrated radiances in a 16 bit Integer*2 word. Trying to implement this technique via the NetCDF unit attributes filed would not be feasible for two reasons: First, the raw data is in an unsigned Integer format that would require conversion to a Real data type before a slope and intercept (scale factor and offset in NetCDF terminology) could be applied. Second, the slope and intercept would have to be varied for each thermal band scan line, which NetCDF does not recommend.

The MAS data set is very large and would therefore would require that all scan line related data be kept physically close together on any potential sequential (e.g. magnetic tape) storage medium. The creation of MAS data using the NetCDF "unlimited dimension" for more than one array of data may produce non localized scan data. This does not appear to be the case upon preliminary examination of the NetCDF format but needs to be explored in greater depth to verify the NetCDF techniques.

NetCDF allows global attributes to be created. This corresponds to header information in a non generic data format. Global attributes can be arrays of data and could include the anchor point index array (scan pixel locations of the anchor points). Global attributes are kept in computer memory.

NetCDF should only use one "unlimited dimension", usually time (or scan number in the MAS case). Having more than one "unlimited dimension" would be required if both the MAS and uninterpolated INS data are to be included in the same data set.

Proposed data set structure:

```
MAS data
    global attributes
        Data descriptor - ASCII
            version number
            flight#, date, etc
        data format specifiers
            data scaling information ...
                        [e.g. I*2=milliW/m^2/sr/wave/scale_factor]
        anchor point index (pixel#)
        wavelength = f(channel#)
        delta wavelength =f(channel#)
    Per scan record (scan#)
        status record (... ,"unlimited")
            bad data bits
            run number [version?] [isn't this a global variable?]
            scan line counter
            thumb wheel switches
            scan rate
            s-bend indicator
            A/C roll count [instrument to A/C ?]
        GMT time ("unlimited")
        Calibration data (band#, "unlimited")
        Science data (pixel#, channel#, "unlimited")
        INS interpolated data ("unlimited")
        Anchor point data (point#, "unlimited")

INS data
    global attributes
        version, date, etc
        time format specifier
    per INS time tag (#)
        GMT time ("unlimited")
        (roll-pitch-yaw-altitude-heading, "unlimited")
```

Questions:

Should the MAS level-1b data set use only Integer data types for portability to platforms that do not support NetCDF? (NetCDF is supported on VMS, UNIX, MS-DOS, OS/2, and MacOS currently)

How should the INS and MAS data sets be organized: separately or combined? They are asychronous in time!

Should the level-1B product be in raw counts with a slope and intercept included, or in radiance values with the slope and intercept applied?

Processing Overview
of the
MODIS Level-1A and 1B
Data Products

10 September 1991

MODIS-N and MODIS-T instrument data are processed by a chain of programs that create various levels of data products. Each data product consists of the MODIS data set and an accompanying set of metadata. The MODIS data set is self contained and includes all instrument (science and engineering/houskeeping) data with a complete dataset header. The metadata duplicates the MODIS data set header with additional information added by the MODIS processes and other processes external to MODIS (the Information Management System for example). This document summarizes the contents of the Level-1A and Level-1B data products that will be available to the user community. Also included is background information describing the flow of the MODIS data from the instrument to the various end user products.

(Note: MODIS-T is used as an example in this document. MODIS-T information is more available than MODIS-N information at the present time.)

Introduction. The Earth Observing Satellite (EOS) Moderate Resolution Imaging Spectrometer - Tilt (MODIS-T) instrument generates three types of data: daylight, night time, and housekeeping. The EOS spacecraft platform generates spacecraft position and attitude information. The data from these sources (and other spacecraft sources) are put into packets and sent through the spacecraft communications system to ground receiving systems (see Figure 1). The data types are determined by the operating mode of the instrument and are mutually exclusive. The details and sizes of each type of data are summarized in the accompanying table labeled "MODIS-T Data Sizing".

The collection of all the MODIS data associated with one complete across track scan is called a scan cube. This concept is visualized in Figure 2. The scan cube is composed of instrument frames (see Figure 3) with science content and separate frames with engineering housekeeping content. Data within a frame are taken simultaneously. Multiple data frames are generated sequentially to create the scan cube. The frames of data are taken as the instrument scan mirror rotates in the across track direction to form the scan cube. Included in each scan cube are the engineering housekeeping data and instrument ancillary data (voltages, currents, thermistor readouts, status bits, etc).

MODIS-T Data Sizing

	daylight	night	housekeeping	(modes)
pixels along track	30	30	30	picture elements
science channels	32	32	32	bands
dark current	2	2	2	bands
pixel precision	13	13	13	bits per pixel
tilt angle	18	18	18	bits per frame
scan angle	18	18	18	bits per frame
time tag	64	64	64	bits per frame
..total frame size	13,360	13,360	13,360	bits per frame
	1,670	1,670	1,670	(Bytes per frame)
ground frames	1,007	16		frames per swath
dark frames	5	5		frames per swath
calibration frames	12	12	1	frames per swath
..total science portion	13,680,640	440,880	13,360	bits per scan
	1,710.08	55.11	1.67	(KBytes per scan)
electronic reference	390	390	390	(30 * 13 bits)
thermistors	48	48	48	Bytes per frame
photo diode	48	48	48	bits per frame
diffuser	4	4	4	bits per frame
aperture	8	8	8	bits per frame
relays	256	256	256	bits per frame
voltages/currents	96	96	96	Bytes per frame
..total engr portion	1,858	1,858	1,858	bits per frame
	232.25	232.25	232.25	(Bytes per frame)
..total scan cube size	13,682,498	442,738	15,218	bits per scan cube
	1,710.312	55.342	1.902	(KBytes per cube)
packet header (.68%)	93,041	3,005		bits (overhead)
..total data size	13,775,539	445,743	15,218	bits per scan cube
scan mirror speed	6.6	6.6	6.6	rev/min
scan cube time	4.545	4.545	13.636	seconds
maximum data rate	3.031	0.098	0.001	megabits per seco
orbital average	40	60	100	percent of coverag
orbital period	98	98	98	minutes per orbit
orbital data volume	891.002	43.246	0.82	MegaBytes per or
	517.44	776.16	143.733	scan cubes per or
daily data volume	13.092	0.635	0.012	GigaBytes per day

A frame of data represents a two dimensional array of solid state detector data with tilt position, scan angle, and time tag appended as illustrated in figure 2. One dimension of the detector array measures

pixel radiance values along the track of the satellite while the second dimension measures radiance at predetermined wavelengths (i.e. bands, channels).

Each data frame is buffered inside the instrument and sent to the spacecraft communications system as packets. A packet is assembled to Consultative Committee for Space Data Systems (CCSDS) specifications and has less than 8196 bits (less than one KByte). A MODIS-T data frame fits into two CCSDS telemetry packets. Each packet starts with an identifier (packet ID), then data from the source, followed by error detection and recovery codes (CRC, etc.).

ID	instrument data (science and engineering)	CRC

Fig 1. Packetized Data
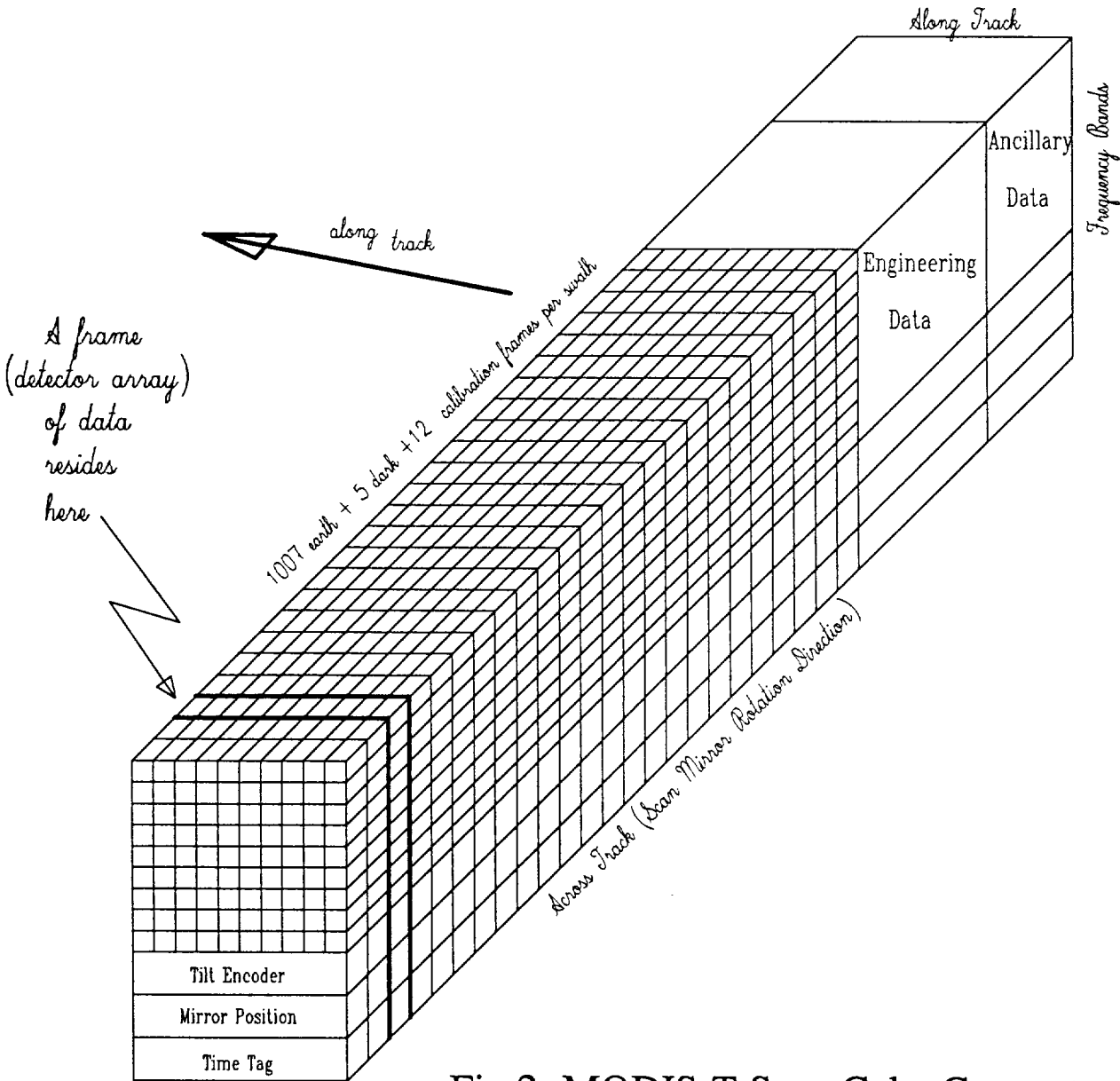
Fig 2 MODIS-T Scan Cube Concept

The spacecraft position and attitude data are obtained from separate telemetered packets of data that are archived by the Data Archive and Distribution System (DADS). These data are localized by time and are contained within the scan cube ancillary data.

<u>Metadata</u>. Metadata, information describing the content, format, and utility of a data set, is associated with each level of the MODIS processing chain. This metadata, generated by each program in the chain of MODIS processes, consists of all previous metadata generated by earlier processes, information appended by programs external to the MODIS chain of processes, and additional information derived from the current program. Metadata grows as the data flows to higher level products.

<u>MODIS</u> <u>Level-1A</u> <u>Data</u> <u>Products</u>. Two data products are produced: the MODIS Level-1A data product containing the scan cubes of data and a separate Level-1A metadata product. The MODIS metadata consists of a superset of the data product header with information appended by programs outside the MODIS processing chain. The MODIS data product will not be altered or replaced by any process other than the MODIS program that generated it. The metadata, however, can have information appended by any process provided that the original information is not destroyed.
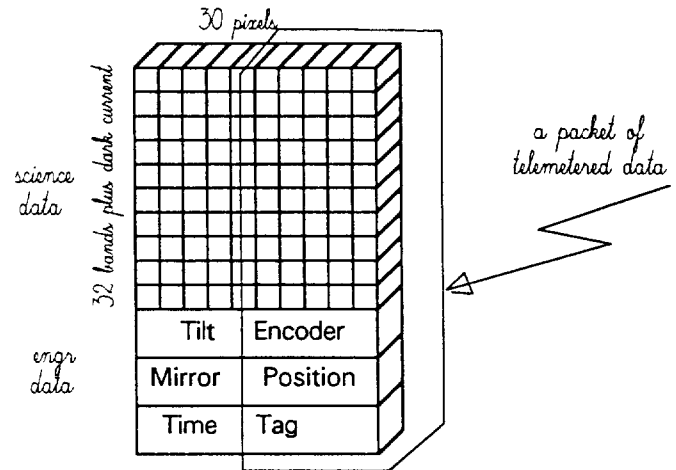
Fig 3. Data Frame

The Level-1A product is derived from the Level-0 Data Product. Level-0 is defined to be the instrument data in packetized form, time ordered with duplicities removed (except for quick look data). The MODIS Level-1A program receives the packets from the (DADS). MODIS processing places the packets of data into computer memory, represented as instrument scan cubes. The scan cube is illustrated in Figure 2. The MODIS program appends spacecraft platform position and attitude information to each scan cube. This information contains the position and attitude information generated ten times per second and grouped within the instrument scan time. This information is not altered or interpolated to instrument scan time.

The scan cubes are placed into the MODIS data product structure, ordered by time, as illustrated in Figure 4. The appended data product header contains the algorithm version numbers, data synopsis and descriptors, etc. Each individual scan cube contains data quality, data completeness indicators, and other items required to further process each scan cube. The Level-1A data will not be unpacked (13 bits into 16 bits) or altered in any way. The Level-1A data product is limited to the raw instrument data with duplicate packets removed and ancillary information appended.

The Level-1A metadata product is created by the MODIS Level-1A program. It includes information from the CDOS packet switching facility, the MODIS Level-1A data product header, and additional data descriptors.

<u>Level-1B</u> <u>Data</u> <u>Product</u>. At-satellite radiances are provided in the Level-1B Data Product. These radiances will be calibrated using an algorithm agreed upon by the MODIS Team members. The calibration algorithm and coefficients will be fixed at the time the MODIS program is executed. Data calibration will be based on the instrument engineering values as inputs to the MODIS Characterization Support Team (MCST) supplied calibration algorithm. This algorithm will not require ground looking (science) data from the instrument for calibration. The calibration algorithm may include a smoothing effect over a plus or minus a several hour time period to minimize abrupt instrument sensitivity changes.

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Ground location will be calculated for a subset of pixels within a scan cube. The locations will be
appended to the data product using the WGS84 (or similar) ellipsoidal Earth model. This does not include a digital elevation model (DEM). Apriori ground location computations based on instrument geometry are expected to provide location to a three sigma accuracy currently specified to be 483 meters. The incorporation of further accuracy improvements derived from ground point convolutions are being considered as a future enhancement.

No correction for atmospheric effects will be included or applied to the radiance values or the anchor point determination. Scene characterization flags (cloud, land, ocean, etc) will be not be included in the Level-1B data product. These flags will be determined in the Level-2 and later processes.

All metadata from Level-1A will be enhanced and appended to produce the Level-1B metadata. Previous metadata values are retained with new information added to produce the current metadata.

Conceptually, the MODIS Level-1B scan cube within the Level-1B data product is the same as the Level-1A scan cube illustrated in Figure 2. The data are byte aligned (unpacked) and will have the selected ground anchor point (geolocated) locations appended. The along track spatial coverage of the scan cubes within the data product is to be determined (TBD).

General Considerations. The MODIS processes will monitor predetermined instrument items and will generate appropriate messages. These messages will be transmitted to requesting processes or projects. These will provide information about selected problems or anomalies detected from the MODIS telemetry data. Solicited and unsolicited messages will be sent to the scheduling activity (SCA) for status responses and data completion problems respectively. In addition, a MODIS Processing Log will contain all MODIS scheduling times, problems, or event items.

Fig 4 Data Products

Quick look processing, normal processing, and reprocessing will be done with the same version of the algorithm. The MODIS software version will handle all MODIS instrument and product modes. Production of a browse data set (once defined) will be a separate process which may be executed either concurrently or on demand (TBD). Browse products will be generated by subsampling, either spatially, temporally, or in wavelength and may include a lossy compression scheme. Browse products are not used by any program in the chain of processing programs.
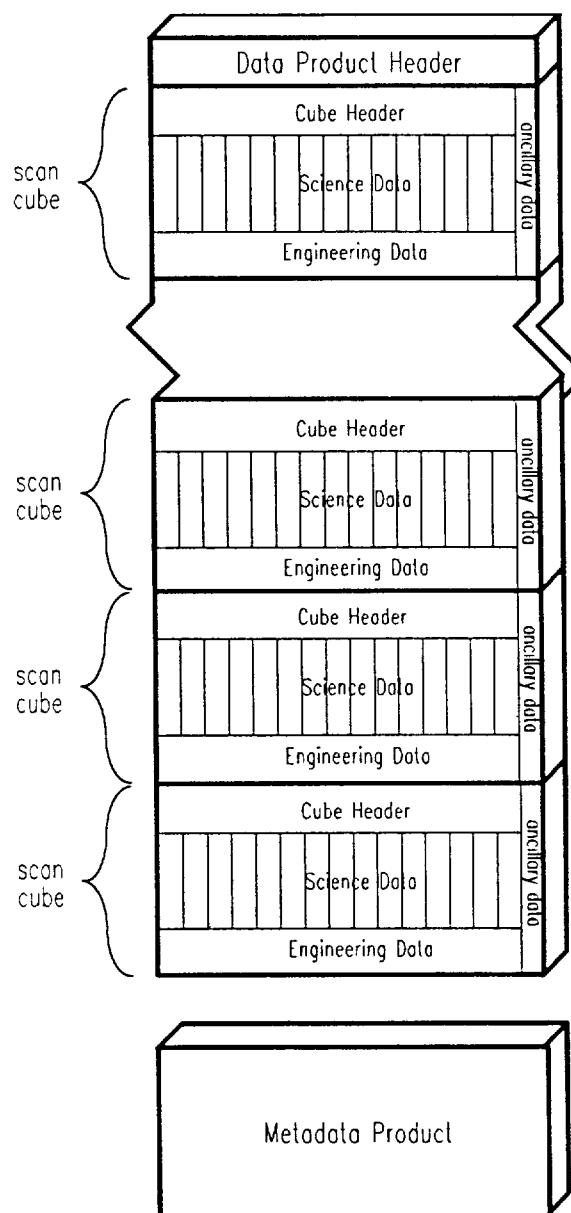
Each program in the MODIS chain of processes will be under configuration management (CM). Calibration algorithms and coefficients, and earth location methods will not be altered. Software program changes will force a new CM revision. Data products will contain a revision indication. MODIS data product will be under CM control once produced. The MODIS metadata will not be under CM control to allow other processes to append information.

MODIS processing algorithms and code will be freely available to interested parties.

MODIS DATA MANAGEMENT PLAN

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MODIS Level-1 Granule Size

Summary

The impact of the MODIS Level-1 data granule size on processing, archival, distribution, etc. was examined and discussed in the MODIS SDST presentations dated June 21, 1991 and June 28, 1991. Several aspects of the impact of the granule size became apparent.

If the Level-1 granule size is "too small", processing MODIS granules individually will be inefficient and inconvenient, especially in connection with the gathering of required ancillary data.

Granule size must be compatible with projected on-line storage capacities of local processing facilities at launch time. A granule size of the order of 100 MByte should be appropriate. This size granule would correspond to a roughly square surface area of continuous MODIS-T data. The same size granule of MODIS-N data would cover a smaller area due to the higher data rate of MODIS-N.

Investigators will need to access subsets containing less than a full granule of data. In many cases only certain bands of data are needed, and a considerable savings in data transmission volume could be realized by band selection. For field campaigns, involving a limited pixel area, and requiring electronic access, crews will prefer to receive just the specific data subsets covering the surface area being investigated.

The data granule size will have an impact on the total volume and usefulness of the metadata which is associated with data granules. With small granules, there would be a larger number of metadata sets to scan through in looking for particular data attributes. For large data granules, the associated metadata would not be as helpful in identifying specific categories of data.

It is possible that the optimum sizes of data granules will be different for processing, archival, and distribution. It is also possible that the EOSDIS will need to be flexible in providing various size distribution granules for various users.